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Mechanical Design of the DØ Silicon Detector

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ABSTRACT

The upgrade of the DØ detector for Run II of the Fermilab collider includes the addition of a silicon tracker for vertex determination. The mechanical structure of the silicon tracker is described.

1. Introduction

The 714240 channel silicon detector for the DØ upgrade[1] comprises seven barrel modules whose symmetry axis is the beamline and 12 disks centered on and normal to the beamline (Fig. 1). Six disks are located between and attached to barrels to form
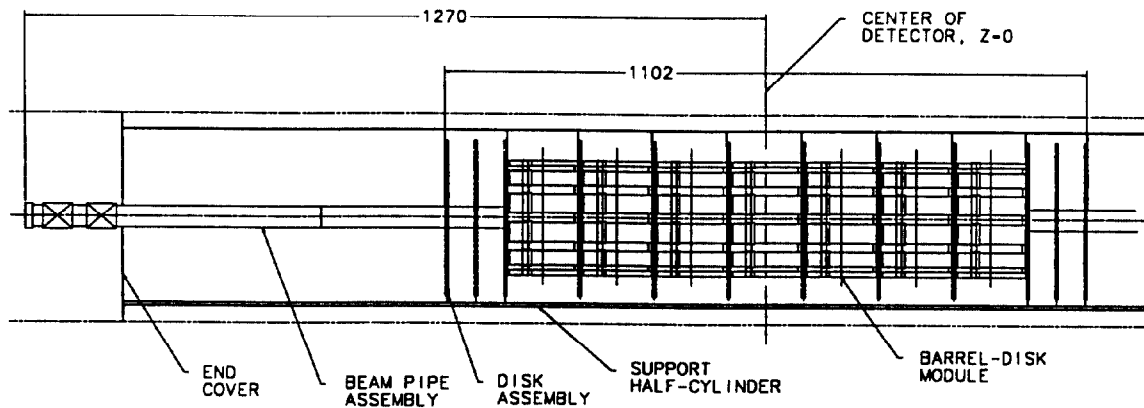

Fig. 1. The DØ Silicon Detector.

"barrel/disk modules". The remaining six disks are joined in sets of three into "end disk modules" located at the ends of the barrel region. The length of the central barrel region is 889 mm; the overall silicon detector active length, including the end disks, is about 1100 mm. The barrel modules and disks are supported within a quasi-hermetic, light-excluding enclosure by a carbon-fiber laminate half-cylinder. The innermost detector radii have been chosen to accommodate a 38.1 mm O.D., 0.5 mm wall beryllium beam pipe. The silicon detector and its cabling and mechanical support structures fit into a 300 mm diameter region within a scintillating fiber tracker.

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2. Barrel Modules

Pairs of 60 mm long, rectangular silicon detectors of each barrel module are held end-to-end on "ladders" (Fig. 2). In addition to the silicon detectors, the ladders contain
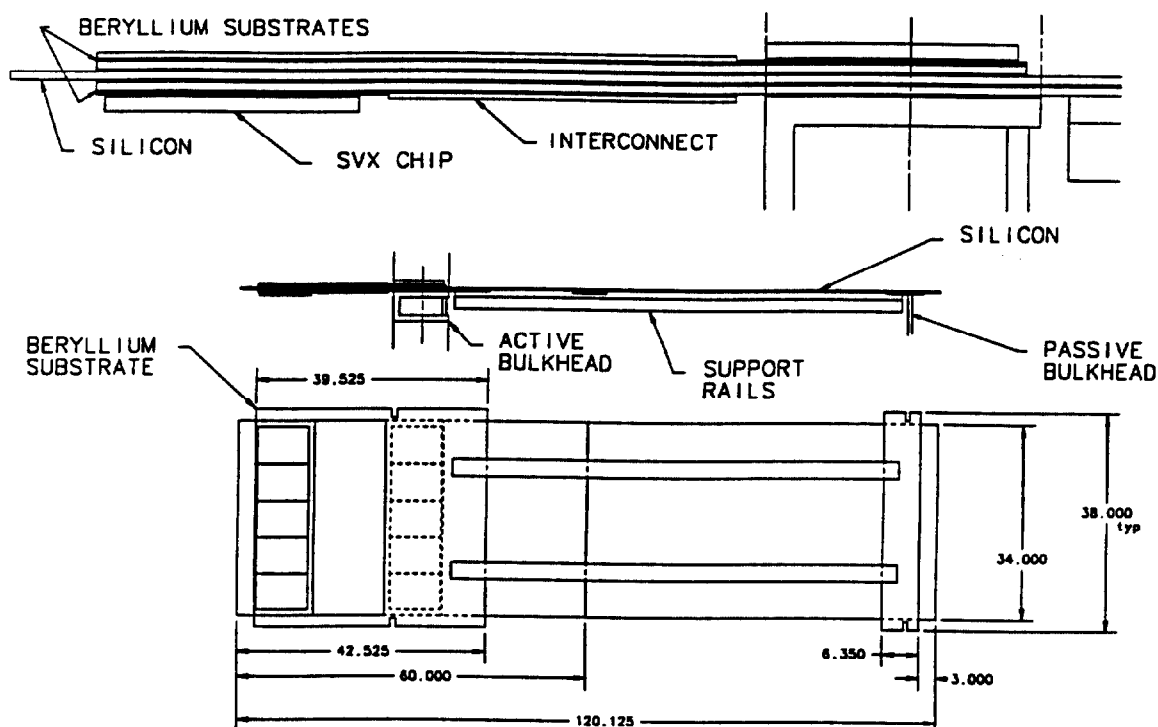

Fig. 2. Five-chip-wide ladder.

128 channel SVX-II chips,[2] transceivers, and a multi-layer kapton/copper interconnect with an integral flatline cable or "pigtail" for external connections. Approximately rectangular, 0.3 mm thick beryllium pieces allow the readout structure to be assembled and tested before it is attached to the silicon, aid in stiffening and supporting the silicon, provide an improved heat transfer path, and provide reference and handling features which allow the ladder to be precisely positioned. The two detectors of a ladder are mechanically connected by two low-mass rails made of a carbon/boron fiber, Rohacell, carbon/boron fiber laminate whose thermal expansion coefficient has been matched to that of silicon.[3] Electrical connections between the detectors of a ladder and to and from the SVX-II chips are made with 25 μm diameter aluminum wirebonds.

The ladders of a barrel are supported and positioned by a 9.525 mm thick, water-cooled beryllium "active bulkhead" and a 0.75 mm thick, uncooled beryllium "passive bulkhead". The ladders are arranged in four layers with equal numbers on inner and outer sublayers. Layer 1 and 3 ladders are 3 SVX-II chips wide and have single-sided silicon with traces parallel to the beamline. Layer 2 and 4 ladders are 5 SVX-II chips wide and have double-sided silicon (5 chips per surface). Traces on one surface are parallel to the beamline and on the other side, at 2° from the beamline. Ladder positions on a bulk-

head are shown in Fig. 3a. Ladder centerline radii range from 27.15 mm to 100.51 mm.
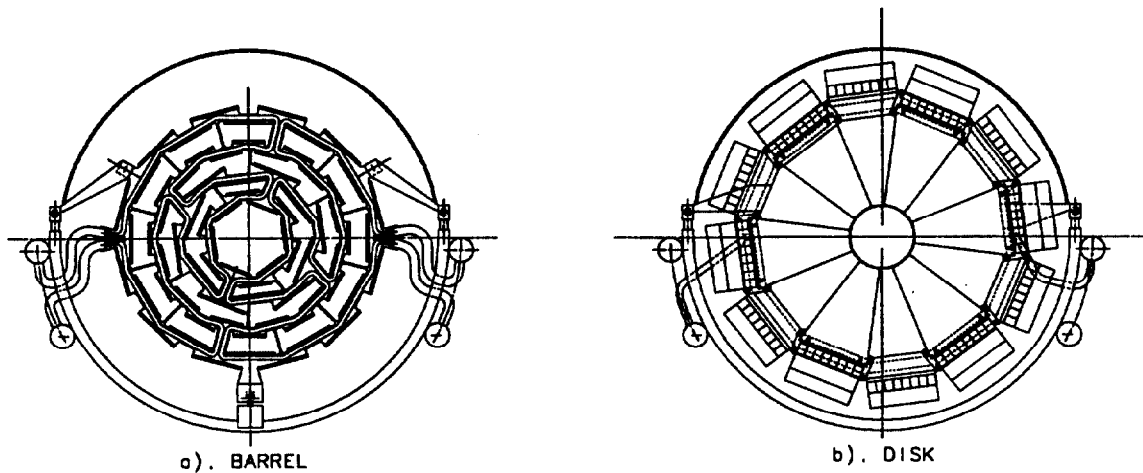

a). BARREL   b). DISK

Fig. 3. End views of barrel modules and disks.

Pigtails follow paths between ladders to the outer radius of each barrel, penetrate the support half-cylinder or its top covers, and connect to cables which run along the length of the outer surfaces. Ladder positions have been chosen to ensure overlap of active regions of inner and outer ladders of a sublayer and to allow adequate space for pigtail paths, cooling channels, and the installation of ladders through the bulkheads.

Fixturing positions the passive bulkhead with respect to the active bulkhead during ladder installation. Epoxy joints between the ladders and the bulkheads allow the ladders themselves to maintain the relative position of the passive bulkhead after the fixturing has been removed and provide a thermal path between the ladder and the active bulkhead. Analysis of the stiffness of the barrel structure[4] has shown that not all ladder layers are needed to hold the passive bulkhead. We have preserved the possibility of using thermally conductive grease joints between the layer 1 and layer 3 ladders and the bulkhead to facilitate replacement of single-sided ladders.

3. Disks

Each disk (Fig. 3b) contains 12 double-sided silicon wedge-shaped detectors, 6 on either surface of a dodecagon cooling and support channel. Traces at $\pm 15°$ on opposite detector surfaces provide 30° stereo. Rectangular readout modules extend radially outward from the silicon wedges with eight SVX-II chips per detector surface. A 0.5 mm thick piece of beryllium supports multilayer kapton/copper structures on which the SVX-II chips and transceivers are mounted and provides a heat conduction path to the cooling/support tube. Wedge pigtails follow paths similar to those of ladder pigtails.

4. Support Structures

A half-cylinder of inner and outer shells of carbon-fiber laminate separated by ribs supports the barrels and disks. As detector elements are installed, compensation will

be made for the predicted 100 μm half-cylinder gravitational deflection.[5] The thermal contraction coefficient of the carbon-fiber laminate is sufficiently low that thermally related half-cylinder deflection should be negligible.

Barrel modules are supported from the active bulkhead only at approximately 2, 6, and 10 o'clock. Vertical leaf-spring connections at 2 and 10 o'clock fix elevation and position along the beamline. A ball and socket connection at 6 o'clock fixes position transverse to and along the beamline. Compliance measurements of the support structure[6] lead to predicted deflections from uncontrolled loadings of less than 6 μm.

The disks of a barrel/disk module are attached to the bulkhead with 6 posts. In our present design, the disks of end disk modules will be formed into a unit with sets of 6 posts. The module will be supported from the center of the three disks in the same way as a bulkhead.

5. Alignment

The barrel bulkhead tolerances have been chosen so that incoherant shifts in ladder positions are less than 25 μm transversely and 170 μm radially.[7] Parallelism to the beamline is achieved by machining mounting features of active and passive bulkheads of a module with the two bulkheads clamped together. Disk positioning tolerances are expected to be similar to those for barrels.

6. Cooling

Power dissipated by the SVX-II chips and transceivers is removed by coolant flowing through passages in the active bulkheads and the disk support channels. The passages and system have been sized for a power dissipation of 3700 watts, a 1°C coolant temperature rise, and a 25% ethylene glycol - water mixture. The coolant temperature will initially be +5°C, but provision has been made for operation as low as −10°C. Measurements of thermal conductivities and heat transfer into the coolant have been combined with finite element analyses to predict ladder and wedge temperature distributions. The highest silicon temperature predicted is 13°C above the coolant temperature. The average silicon temperature obtained is about 4°C above the coolant temperature.

References

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